Physical chemical properties of redeposited layers in T-10 tokamak with graphite and tungsten limiters

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Operation of the T-10 tokamak (NRC “Kurchatov Institute”) with graphite ring and rail limiters showed that in areas of small but prolonged heat loads of 1–2 MW/m2 there was a strong erosion and cracking of the graphite material (MPG-8) limiters. The destruction of the ring limiter in the region of the beam of accelerated electrons was also found. Intensive erosion of graphite led to sputtering of the carbon material and the formation of redeposited carbon layers. The formation of such layers is caused by the codeposition of atomic deuterium formed in the plasma during the discharge and carbon atoms or hydrocarbon radicals, which are products of physical-chemistry sputtering of hot graphite limiters. In general, hydrocarbon films covered the relatively cold walls of the vacuum chamber and the tokamak pumping system [1].

The study of the physical chemistry properties of hydrocarbon films was carried out both for “free” films collected from the elements of the inner surface of the tokamak chamber and for films deposited on special substrates made of silicon, quartz and molybdenum. By using of spectrophotometry, ellipsometry, and X-ray photoelectron spectroscopy, the composition, structure, as well as optical and electro-physical properties of the films have been studied in detail. It is shown that the films formed in tokamak can be divided into two types, which differ significantly in their optical, electrical and mechanical properties. The temperature dependence of the electrical conductivity G(T) of these films was investigated. The values ​​of the activation energies of the conductivity Ea were determined in the temperature range 293–550 K. It was shown that G(T) and Ea depend on the type of film and are determined by the discharge parameters in the tokamak [2].

The replacement of graphite limiters with tungsten in 2015 and an increase in the ECR power of plasma heating from 2 to 3.5 MW also led to erosion and damage to the material of the limiters [3]. To reduce heat fluxes on the T-10 tokamak wall, an additional lithium limiter was installed in the chamber. The sputtered layers were found in the lower part of tungsten elements of ring limiter. To study the effect of tungsten on the parameters of deuterium plasma, a tungsten sample, which was a fragment of the prototype of the protective coating of the diverter ITER, was introduced into the plasma on a special holder. Quartz and sapphire substrates were fixed on the same holder to collect the sputtered material. Composition and structure of the layers are investigated in detail. Conclusions were drawn about the possible influence of such layers on the operation of the T-10 tokamak and ITER.

Thus, the collection, systematization, and study of the physical chemistry properties of films can provide important information not only on the type and properties of the redeposited layers themselves, but also on erosion and sputtered processes, as well as the parameters of plasma discharge in a tokamak.

References

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